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Effects of Matrix Training on Generative Language in Young Adults with Autism

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Thesis Submitted in Partial Fulfillment of the Requirements for the
Degree of Master of Arts in Education

California State University, Monterey Bay

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Effects of Matrix Training on Generative Language in Young Adults with Autism

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Abstract

Many young adults diagnosed with autism require thorough instruction that can be labor- and time-intensive, and a focus on generalization of learned skills must be incorporated into effective instructional techniques. Matrix training aims to address each of those considerations by providing a framework for systematic selection of targets to be taught to individuals so that instructional gains are maximized. A multiple-baseline across participants A-B-C design was used in the present study to investigate the effects of matrix training on the generalization of color and shape tacts (labels) for three young adults with autism. It was hypothesized that organizing concepts across a matrix and systematically teaching targets that fell along the diagonal line of the matrix would increase accurate responding when the remaining untaught targets were tested in the final phase of the study. The findings from this study are consistent with prior research in that matrix training was found to be effective in increasing participants' ability to generalize new combinations of taught colors and shapes. Additional studies are warranted to explore the use of matrix training paired with other instructional strategies, to teach different skills, and with more diverse populations.

Keywords: matrix training, recombinative generalization, generative language, discrete trial training, autism

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Effects of Matrix Training on Generative Language in Young Adults with Autism

Literature Review

According to the *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.; DSM-5; American Psychiatric Association, 2013), autism spectrum disorder (ASD) is characterized primarily by communication deficits, social challenges, and the presence of restricted or repetitive patterns of behavior. Individuals diagnosed with ASD frequently display language delays in both expressive language (e.g., conversations, labeling, requesting) and receptive language (e.g., comprehension of language). These characteristics are present in early development and significantly impact functioning across multiple aspects of life (Alpern & Zager, 2007); therefore, it is imperative that instructional strategies used to teach these skills are evidence-based and efficient.

Seltzer and colleagues (2003) conducted a study analyzing communication, reciprocal social interaction, and restricted or repetitive behaviors and interests in adolescents and adults with ASD. Several of the communication skills that were significantly different from those of typically developing individuals included overall use and level of language, stereotyped utterances, and non-verbal communication skills such as head nodding and shaking and use of gestures. Additionally, Alpern and Zager (2007) noted difficulties adults with ASD experience with regard to understanding conversational aspects of language such as idioms, double-meanings, body language, and knowing when and how to ask questions or make comments. These language challenges can make it difficult for individuals with ASD to engage in appropriate social interactions, participate in their community, and communicate their wants and needs adequately; thus negatively impacting their performance in social and vocational settings.

Effective teaching is required to mitigate the aforementioned communication challenges for young adults with ASD. However, teaching language skills to individuals with ASD can be time-consuming and intensive. Oftentimes expressive language skills are taught in a way that elicits rote memorized responses, and these responses are not easily generalized to other stimuli. This causes communication exchanges to appear less natural and stand out as abnormal. Additionally, explicitly teaching a specific response for every possible situation an individual may encounter would be impossible; therefore, it is important to design effective programs that include generalization components to promote accurate responding across situations, settings, and people (Baer, Wolf, and Risley, 1968). The ability to generalize learned language skills enables people to engage in more fluid, naturalistic communication, which can significantly improve the level of inclusion and functioning for someone with ASD. Generative language is one of several terms used to describe this skill (see also verbal generativity, generative responding, recombinative generalization); it is a desired outcome across many teaching strategies used to teach individuals with ASD (LeBlanc, Esch, Sidener, and Firth, 2006).

Overview of Approaches to Teaching Language

There are a multitude of strategies for increasing language skills with individuals with ASD, most of which fall under the categories of either applied verbal behavior (AVB) approaches or naturalistic teaching approaches (NTA; LeBlanc et al., 2006). Some common types of NTA include incidental teaching (see Charlop-Christy & Carpenter, 2000; Hart & Risley, 1968; McGee, Morrier, & Daly, 1999), mand-model training (see Rogers-Warren & Warren, 1980), and pivotal response training (see Koegel, Koegel, Harrower, & Carter, 1999). Both AVB and NTA are used to teach a variety of language skills that have been identified as problematic for individuals with ASD; these challenges with language skills persist through childhood and into adolescence. Specific challenges include receptive language skills (e.g., following directions and identifying stimuli) and expressive language skills (e.g., requesting, echoing, labeling, answering questions; LeBlanc et al., 2006). Both approaches to teaching language skills to individuals with ASD – AVB and NTA – share commonalities and have been effective in increasing functioning in the aforementioned areas for some students. Understanding both approaches is essential in creating effective teaching strategies for those with ASD.

Naturalistic Teaching Approaches (NTA)

According to LeBlanc and colleagues (2006), NTAs began gaining traction in the 1970's and 1980's when practitioners (see Stokes & Baer, 1977) began emphasizing skill generalization and mimicking the natural conditions in which one might use language. NTAs tend to focus on teaching that can take place in the naturally occurring language contexts. For example, these environments may include the child's home, daycare, or school setting. Furthermore, the contexts also include naturally occurring events such as play or other predictable events that may occur during the child's day (Charlop-Christy, LeBlanc, & Carpenter, 1999). Different to AVB strategies, NTAs utilize naturally occurring situations and reinforcers for promoting the use and development of language rather than the manipulation of discriminative stimuli.

There are a variety of naturalistic teaching approaches that have been researched. One such approach is incidental teaching (IT). IT occurs in the natural environment, requires that available reinforcers are contingent on the use of targeted language skills, and is focused on increasing spontaneous language and generalization (LeBlanc et al., 2006). However, IT offers an unpredictable amount of opportunities for students to demonstrate skills due to the fact that the teacher does not set up or stage opportunities, but rather the student is *driving* the learning session (Charlop-Christy & Carpenter, 2000). In other words, if a child is being taught to request an item and the child only shows motivation for the item one time in a 30-minute session, then that is the only opportunity for a teaching trial. Repetition and practice of skills are key elements of effective teaching strategies for students with ASD (e.g., direct instruction, discrete trial training), therefore the potential lack of repetition while using IT could prove problematic.

Additional NTA's include the Mand-Model procedure developed by Rogers-Warren and Warren (1980), the natural learning paradigm (NLP) developed by Koegel, O'Dell, and Koegel (1987), and Pivotal Response Training (PRT; Koegel & Koegel, 2012). These strategies are supported by research as evidence-based practices and incorporate student motivation and naturally occurring environmental stimuli in order to facilitate communication skills. Similar to IT, however, these strategies are largely student-led and thus the same issues of repetition and practice may be present. Other concerns with NTAs stem from B. F. Skinner's conceptualization of verbal behavior. As Sautter and LeBlanc (2006) discuss, Skinner identified distinct verbal operants that function independent of each other and as such, need to be taught in specific conditions in order to be learned in various contexts. For instance, an individual taught to request "cookie" when a cookie is present and is delivered to them after a correct request may not be able to label it as "cookie" when shown a cookie and asked, "What is it?" (Skinner, 1957). If a concept was only taught when a student was motivated for an item and in that one specific context, generalization of the concept may not readily occur. Due to this concern, NTAs were not selected for use in the present study.

Applied Verbal Behavior (AVB)

Applied Verbal Behavior (AVB) strategies provide a solution to the possible lack of repetition seen in IT. AVB approaches are based in Skinner's conceptualization of language as being verbal behavior that is socially mediated and reinforced (Skinner, 1957) and is defined by its antecedents (e.g., what occurs prior to the behavior) and consequences (e.g., what happens after the behavior; Sautter & LeBlanc, 2006); therefore, instructional strategies based on this conceptualization utilize the manipulation of antecedents and consequences. That is, AVB teaching conditions (e.g., environmental and instructional cues) are manipulated to set up more frequent opportunities for the child to demonstrate a specified skill, and additional reinforcers are typically available for correct responding (LeBlanc et al., 2006). That means that the number of possible teaching opportunities can be higher than with NTAs because it does not rely on a student's motivation for the target item.

Discrete Trial Training (DTT) is a well-known application of AVB approaches. Geiger and colleagues (2017) describe DTT as commonly occurring as part of interventions targeted toward children with ASD, but the approach can also be used in settings that serve adults with ASD as many of the challenges in childhood continue to present through adulthood. DTT involves rapid presentations of discriminative stimuli, prompting, and consequences for responding. This means materials or stimuli are presented quickly and frequently with varying levels of assistance being provided to the person with ASD based on their performance. In addition, responses are either reinforced (e.g., through praise, preferred items or activities) or punished (e.g., corrective feedback is given, no social praise delivered). Reinforcement for correct responding is a main component of DTT and, unlike in NTA’s, reinforcers are not typically naturally occurring within the situation but rather include externally controlled reinforcers such as food, tangible items, or social praise. According to Delprato (2001), these approaches that stem from operant behavioral procedures have been shown to improve language use in children with ASD. However, Spradlin and Siegel (1982) identify several challenges with behavioral approaches, including difficulty generalizing skills acquired across settings and to the natural environment, indicating that AVB approaches alone may not be sufficient for promoting generalization of language skills.

Generative Language

Both AVB approaches and NTAs share a common goal of increasing generalization (LeBlanc et al., 2006). As mentioned previously, young adults with ASD have language challenges that are most commonly addressed through teaching specific scripted responses regardless of the use of AVB or NTAs, which can make communication sound unnatural and leave the individual with only those specifically taught words or phrases. In order to mitigate some of those possible effects, teaching to promote generative language (e.g., the ability to generalize the use of language skills across situations) is a desirable goal for practitioners working with individuals with ASD.

In order to conceptualize the approaches to teaching generative language, one must understand the ideas of response and stimulus generalization. Stewart, McElwee, and Ming (2013) identify response generalization as a key process that underlies language generativity; it enables people to respond to new circumstances they have not encountered before. More specifically, this phenomenon occurs when similar but non-identical responses can occur under the control of a certain stimulus. An example of this would be if someone was asked to label a picture of a cat using the word "kitty," and then demonstrated the ability to label the same picture with the word "cat."

Stimulus generalization refers to the opposite. That is, the same response occurs under the control of different but similar stimuli. For example, someone who has learned to label a picture of their pet cat with the word "cat" would demonstrate response generalization if they are then able to label a picture of a *different* cat with the word "cat." Stewart and colleagues (2013) continue to conceptualize this by noting that the *lack* of response generalization is often referred to as rote verbal responding, in which an individual consistently responds to a given stimulus in the exact same way. Rote verbal responding can be a barrier to social communication in individuals with ASD; understanding the processes behind generative language is imperative for implementing effective strategies.

Approaches to Teaching Generative Language

As mentioned prior, generalization is a concern for practitioners using AVB approaches (e.g., discrete trial training) to teach students with ASD. LeBlanc and colleagues (2006) speak to generalization of treatment effects being important for people who use AVB strategies, and notes that one common way of achieving this is through natural environment training (NET). NET capitalizes on naturally occurring opportunities to teach skills in appropriate contexts. Multiple exemplar training is another generalization strategy incorporated in AVB approaches. According to LeBlanc and colleagues (2006) these strategies follow established frameworks and guidelines (see

Stokes and Baer, 1977) to increase generalization of language that can occur in different contexts. In addition to those strategies, Axe (2016) identifies equivalence-based instruction, derived relational responding instruction, and matrix training as the most common interventions for increasing generative language in AVB approaches. Approaches falling under the category of equivalence-based instruction are found to be efficient and effective methods of training, and therefore have serious implications for education for individuals with ASD (Stewart et al., 2013). Additionally, derived relational responding instruction has been shown to be a significant factor in the development of language (O'Hora, Pelaez, & Barnes-Holmes, 2005).

Matrix Training

Matrix training is the final common approach to teaching generativity; it should be conceptualized not as its own intervention, but one that can be used *with* the aforementioned strategies (e.g., AVB or NTA approaches) to teach generative language. Matrix training attempts to solve the issues of lack of generalization and length of time and labor it can take to teach concepts (some of the challenges of teaching language skills to individuals with ASD; Schreibman et al., 2015) by creating a framework for a more systematic selection of targets to be taught in the hopes that purposeful selection of targets will increase the efficiency of teaching. Matrix training is commonly used with DTT, and is a way to organize targets to be taught in order to maximize instruction.

To conceptualize this approach, it must be noted that it is not a different *form* of teaching, but rather is a way of systematically selecting what is taught so that generalization of skills is more likely. Axe and Sainato (2010) state that in matrix training, targets are arranged in a matrix. The target items that fall on the diagonal line of the matrix are directly taught, most commonly using DTT, while the other targets are not. For example, if you were teaching a student to identify pictures using both a noun and an adjective (e.g., "red ball"), you would arrange a matrix with nouns on one side and adjectives on the other. A 3-by-3 matrix may, then, include columns for red, blue, and yellow, and rows for ball, dog, and cup. See Table 1 below for an example of a matrix.

Table 1

Matrix Training Table

	Red	Blue	Yellow
Ball	Red Ball	Blue Ball	Yellow Ball
Dog	Red Dog	Blue Dog	Yellow Dog
Cup	Red Cup	Blue Cup	Yellow Cup

Note. Table 1 displays each noun and adjective combination for the nouns ball, dog, and cup, and the adjectives red, blue, and yellow. Highlighted targets along the diagonal are selected for explicit teaching during a matrix training intervention.

In arranging targets this way, although there are only three targets selected for explicit teaching (i.e., the shaded cells in Figure 1), all concepts are represented (red, blue, yellow, ball, dog, cup, and all combinations of those). Matrix training for language skills relies heavily on the concept of generative language. That is the taught concepts (e.g., nouns and adjectives) are recombined when an individual is presented with novel stimuli. As stated by Axe and Sainato (2010), matrix training has been shown to be effective in teaching receptive language skills as well as expressive skills including labeling with multicomponent phrases (e.g., labeling color-object combinations) to children with cognitive delays. Because these language skills continue to be challenging for young adults with ASD, it is likely to be an effective intervention for individuals aged 15-22 years old as well. While research on matrix training is fairly limited, a number of studies have shown it to be an effective approach to promoting generative language (Axe & Sainato, 2010; Dauphin, Kinney, Stromer, & Koegel, 2004; Frampton, Thompson, Bartlett, Hansen, & Shillingsburg, 2018; Kohler & Mallot, 2014).

In each of the studies discussed in this section, matrix training is used *in conjunction* with an evidence-based instructional strategy (e.g., video modeling, task analysis, DTT). In one study by Kinney, Vedora, and Stromer (2003), spelling was taught through video modeling and then was probed using novel words. The participant was able to generalize and recombine consonants and word endings after the training phases were complete. Another study performed by Dauphin, Kinney, Stromer, and Koegel (2004) used task analysis and matrix training to teach an individual with ASD and ADHD to say four-word phrases and perform object-action combinations. They used prompting and prompt fading strategies (e.g., gradually decreasing the amount of assistance provided to the participant) to teach the initial targeted combinations, then probed untaught combinations and found that the participant was able to perform most of the new tasks even when not explicitly taught. Axe and Sainato (2010) performed their own research in which they arranged actions, pictures, letters, and numbers in matrices. The results indicated that participants were able to consistently produce novel responses during post-teaching probes. As Axe and Sainato (2010) discuss, the results of this study support the findings of previous research demonstrating the positive effects of matrix training on many aspects of language that are typically problematic for children with ASD including receptive and expressive language. However, more research is needed to demonstrate how matrix training can be used with young adults with ASD.

Method

Prior research demonstrates the effectiveness of matrix training in combination with evidence-based practices in teaching new skills to individuals with ASD (Axe & Sainato, 2010; Dauphin, Kinney, Stromer, & Koegel, 2004; Frampton, Thompson, Bartlett, Hansen, & Shillingsburg, 2018; Kohler & Mallot, 2014). Most available research on matrix training has focused on its application with children with ASD; the present study aimed to further examine the effects of matrix training on generative language (i.e., the ability to produce novel language) as it pertains to teaching young adults with ASD. The skill of labeling pictures using an adjective + noun phrase was selected for this study as it is a foundational skill that has many applications that are relevant to young adults with ASD (e.g., using descriptive language, conversation skills, vocational tasks such as sorting).

Research Question

Does matrix training increase generative language in 2-component labeling (i.e., adjective + noun) in young adults ages 15-22 years old diagnosed with ASD?

Hypothesis

Kinney, Vedora, and Stromer (2003) used matrix training to teach spelling (more specifically, combining consonants with common word endings) through video modeling, then probed new words that used the same consonants and word endings but in different combinations. The participant was able to generalize and recombine consonants and word endings after the training phases were complete, indicating that the use of matrix training was effective in increasing generative language. A similar study demonstrated the effectiveness of matrix training in teaching participants to say 4-word phrases and perform object-action combinations even when not explicitly taught (Dauphin, Kinney, Stromer, & Koegel, 2004). The results of these studies are consistent with previous studies finding increased generative language after matrix training. Based on the available research demonstrating the effectiveness of matrix training in promoting generative language in children with ASD, it was hypothesized that the use of matrix training in combination with another evidence-based strategy (i.e., DTT) would increase the number of novel stimuli (e.g., images that have not been explicitly taught to the participants) that the young adults in the study responded to correctly by using 2 language components (i.e., adjective + noun).

Research Design

The research was performed using an A-B-C concurrent multiple baseline across participants design (Kennedy, 2005). As the independent variable was a teaching strategy, there was no way to remove the intervention because the participant would have already acquired the taught skill; therefore, a reversal design could not be used. Using multiple baseline across participants, rather than across settings or behaviors, addressed the effectiveness of the treatment on the application of the same skill across different students with unique learning needs, enhancing the reliability of the study. The study began with a baseline phase (Phase A) in which participants' prior knowledge was assessed for each of the 9 targets in the matrix (see Appendix A). In Phase B, the targets that fell along the diagonal line of the matrix (see Appendix A) were then taught to participants using DTT procedures, errorless learning and prompt fading (Frampton et al., 2018). Once mastery of each of the targets on the diagonal occurred (i.e., the participant responded with 100% accuracy for 3 consecutive days for each), Phase C began. Phase C, or the generalization phase, assessed participants' abilities to recombine taught concepts (i.e., nouns and adjectives) learned during Phase B by applying them to novel or untaught images. In this phase, all untaught targets remaining in the matrix (e.g., all targets that were *not* on the diagonal line) were tested. Detailed descriptions of each phase as well as transitions between phases for each participant are provided in the Procedures section below.

Independent variable. Matrix training was the independent variable and was defined as the process by which targets taught to participants were organized in a matrix with different components on each axis. In this study, participants were taught to label 2D images using adjective + noun combinations. Therefore, nouns were arranged on one axis of the matrix, and adjectives along the other (see Appendix A). Simple adjectives and nouns were selected for teaching as they are foundational concepts for descriptive language, which is a skill that can ultimately improve conversational skills. Methods based on the study performed by Mueller, Palkovic, and Maynard (2007) were used, including DTT (i.e., rapid presentations of discriminative stimuli, prompting, and consequences for responding) with errorless learning (i.e., the use of prompts to minimize of the chance of participants making an error or mistake) and prompt fading strategies (e.g., the gradual decreasing of assistance to participants; Billingsley & Romer, 1983). A full description of procedures is provided below in the Intervention section.

Dependent variable. Generative language was conceptually defined as the ability to produce and understand novel language components without being explicitly taught to do so (see Hayes, Barnes-Holmes, & Roche, 2001). However this study only addressed participants' ability to produce novel language. Generative language was measured in this study by the number of untaught or novel stimuli participants were able to label correctly in the generalization phase of the intervention. Throughout the study, data was collected using the 2-Component Labels Data Sheet (see Appendix B) and analyzed daily to inform data-based decisions for prompt-fading (i.e., decreasing or increasing assistance to the participant) and transitions between phases A, B, and C. A full description of procedures is provided below in the Intervention section.

Intervention

A 3x3 matrix containing targets for the 2D images was created with nouns along one axis and adjectives along the other (see Appendix A). All targets were probed (i.e., presented without any consequences for responding, either correction or reinforcement) during the baseline phase (Phase A). After baseline data demonstrated stability (i.e., 5 consecutive data points at below 50% accuracy), the intervention phase (Phase B) began in which the three targets falling along the diagonal line of the matrix were simultaneously explicitly taught using DTT methods (i.e., rapid presentations of discriminative stimuli, prompting, and consequences for responding), errorless teaching (i.e., the use of prompts to minimize of the chance of participants making an error or mistake), and prompt fading (e.g., the gradual decreasing of assistance to the participant). Specific prompt fading procedures are outlined below under Procedures. Once each target on the diagonal line was mastered (i.e., the participant responded independently for 100% of sessions for each target for 3 consecutive data points) in Phase B, the generalization phase (Phase C) was initiated; during this time, the remaining targets on the matrices that were not taught were probed to see if generalization of the components occurred.

Procedures

Baseline. The Baseline phase (Phase A) began simultaneously for each participant. Baseline data was collected in the beginning of the study to demonstrate each participant's current level of performance with using adjective + noun phrases to label the target 2D images in the matrix (see Appendix A). During this phase, each baseline session occurred in a DTT format in which other high probability directions (e.g., “show me clapping,” “say ‘monkey’”) were presented to the participant to gain attention and behavioral momentum; each of the 9 target images were then presented along with the verbal direction “what is it?” These presentations were interspersed with the high probability directions. No feedback (i.e., error correction or reinforcement) was provided to the participant regardless of their response to avoid the possibility of teaching the response (Frampton et al., 2018), however reinforcement was provided for correct responses to the other high probability tasks and for student behavior. Five baseline sessions (i.e., a 5-10 minute DTT session containing probes for each of the 9 matrix targets and interspersed high probability directions) occurred in a day.

Treatment phase. The treatment phase was initiated when Participant 1 demonstrated stable baseline responses for five consecutive days (i.e., 5 consecutive data points with below 50% accurate responding); the remaining participants continued to experience the baseline phase (Phase A). During the treatment phase, the three targets that fell along the diagonal line of the matrix (see Appendix A) were simultaneously taught using errorless learning and prompt fading procedures utilized in DTT (i.e., the use of rapid presentations of discriminative stimuli, prompting, and consequences for responding). Prompting procedures followed a most-to-least hierarchy (Libby, Weiss, Bancroft, & Ahearn, 2008). The prompt fading strategy selected after a review of student learning histories was as follows: verbal prompt, verbal prompt with a transfer trial, verbal prompt with a transfer trial and 3 distractor tasks, and independent responding as the final step. See below for an example of the prompt fading steps listed from most-to-least in the order the participants experienced them:

1. Verbal Prompt: *Experimenter (presents stimulus): "Red circle. What is it?" Participant: "red circle."*
2. Verbal Prompt with Transfer Trial: *Experimenter (presents stimulus): "Red circle. What is it?" Participant: "red circle." Experimenter (presents stimulus again): "What is it?" Participant: "Red circle."*
3. Verbal Prompt with Transfer Trial and Distractor Tasks: *Experimenter (presents stimulus): "Red circle. What is it?" Participant: "red circle." Experimenter (presents stimulus again): "What is it?" Participant: "Red circle." Experimenter presents 3 distractor (e.g., previously mastered) tasks: "touch your nose," "say 'bee'," "what is your mom's name?" Participant: responds to 3 questions or demands. Experimenter presents stimulus one additional time: "what is it?" Participant: "Red circle."*
4. Independent Response: *Experimenter (presents stimulus): "what is it?" Participant: "Red circle."*

Prompts for a specified target were faded (i.e., gradually decreased based on student performance) each time the participant met criteria (i.e., the participant responded correctly with the specified prompt level for 100% of sessions for each target for 3 consecutive data points) until the participant was able to answer the question "what is it?" accurately and independently (i.e., without any prompts from the experimenter). If at any point incorrect responses were provided, the following error correction procedure occurred: prompted response, independent response, three consecutive distractor tasks (i.e., mastered or high-probability directions), and a final independent response (Frampton et al., 2018). An error correction for red circle for example followed this process:

1. Prompted Response - *Experimenter: "red circle - what is it?" Participant: "red circle."*
2. Independent Response - *Experimenter: "what is it?" Participant: "red circle."*
3. Three Distractors - *Experimenter: "say elephant," "what is your name?" "what color is my shirt?" Participant: answers each question.*
4. Final Independent Response - *Experimenter: holds up red circle again and asks "what is it?" Participant: "red circle"*

There were additional criteria for prompt fading if the data for any target was unstable (i.e., variable or bouncing data) or not increasing for longer than three days; these criteria were in place to reduce participant errors, an integral part of errorless learning. If this occurred, a change in the magnitude or type of prompt was made (e.g., a participant was not improving when the experimenter was providing a verbal prompt with a transfer trial, so the prompt was changed back to a full verbal prompt). Once a participant demonstrated mastery of each of the three targets (i.e., the participant responded independently to each target with 100% accuracy for 3 consecutive days), the generalization phase was initiated. Participant 2 (still in the baseline phase at this point) started the treatment phase once a therapeutic trend (i.e., an increase in correct responding) was achieved for Participant 1 in the treatment phase. Participant 3 remained in baseline until Participant 2 demonstrated a therapeutic trend in the treatment phase, at which point they began treatment.

Generalization phase. During the generalization phase, the researcher probed the remaining 6 untaught targets in the matrix (Frampton et al., 2018) while maintaining the 3 targets mastered during Treatment. Therefore, a session during the generalization phase mirrored that which occurred in baseline in that all 9 targets were presented to the participants during each of the 5 DTT sessions. Different from the baseline phase however, consequences for participants' responding (i.e., error correction and reinforcement) were utilized during the generalization phase. Error correction procedures followed the same steps as in the intervention phase (see above), and reinforcement (e.g., access to preferred items or activities) along with verbal praise was delivered when participants responded correctly. The generalization phase concluded once participants demonstrated 5 stable data points at 80% responding or higher.

Setting & Participants

The setting was a non-public school for children with moderate to severe ASD or other developmental disabilities located in Central California. The school served 48 students between 8 and 22 years old diagnosed with ASD or other developmental disabilities. No data was available regarding ethnicity and language demographics for the school. Each student had a behavior intervention plan (i.e., protocols containing definitions for maladaptive behaviors, proactive strategies, and consequences when the behaviors occur), an individualized education plan (i.e., a document with specific educational goals for an individual student), and at least one instructional aide at all times throughout the day unless otherwise noted in their individualized education plan (IEP). The school utilized teaching approaches based on principles of applied behavior analysis (ABA) to teach the students new skills and reduce maladaptive behaviors (e.g., aggression, self-injury, property destruction, etc.).

Purposeful convenience sampling was used to select three participants from the school based on the following criteria adapted and expanded from the criteria used by Frampton and colleagues (2018): between 15-22 years old, communicated verbally or through augmentative and alternative communication (AAC) using utterances of at least one word, able to label at least 50 2D images using one word or label 2D images with two components following a model, and able to receptively identify (e.g., select the correct picture from an array) at least 50 2D images.

The aforementioned criteria were put in place to ensure participants demonstrated necessary prerequisite skills to labeling images with two language components. Participants with significant challenging behavior (e.g., high rates of self-injury, aggression, non-compliance) were excluded from the sample to ensure safety of participants and researchers as well as the reliability of the study. Information on participant eligibility was obtained through a review of student records (i.e., current and recent IEP programming and assessments) and teacher interviews. The participants selected were representative of the population in that they fell within the target age range, were diagnosed with ASD, and displayed significant learning and communication challenges. Pseudonyms were used to ensure confidentiality of the participants.

Amanda. Amanda was an 18-year-old white female student with a primary diagnosis of ASD. She communicated verbally in English using an average of 3 to 5 words per utterance and demonstrated the ability to label items or objects using two language components after being given a model. Amanda occasionally engaged in disruptive and self-injurious behaviors, though analysis of the antecedents to her behaviors did not demonstrate that they occurred in response to work tasks, and the rates of these behaviors were not sufficient to disqualify her from the study. All procedures noted in her BIP were implemented throughout the study.

Charles. Charles was a 20-year-old Hispanic male with a primary diagnosis of ASD. He communicated verbally in English using an average of 3 to 5 words per utterance and demonstrated the ability to label at least 50 common objects or items and label objects or items using 2 language components after being given a model. Charles occasionally engaged in off-task, repetitive, and aggressive behaviors, though analysis of the antecedents to these behaviors did not demonstrate that they occurred in response to work tasks, and the rates of these behaviors were not sufficient to disqualify him from the study. All procedures noted in his BIP were implemented throughout the study.

Emily. Emily was a 21-year-old Filipino female with a primary diagnosis of ASD. She communicated using a speech generating device on her iPad in English using an average of 3-5 words per utterance. She demonstrated the ability to label at least 50 common objects or items and label objects or items using 2 language components after being given a model. Emily occasionally engaged in destructive and aggressive behaviors, though analysis of the antecedents to these behaviors did not demonstrate that they occurred in response to work tasks, and the rates of these behaviors were not sufficient to disqualify her from the study. All procedures noted in her BIP were implemented throughout the study.

Measures

Similar to the study by Frampton and colleagues (2018), data was collected on participant responses using a paper and pencil data sheet that specified the stimulus conditions and response requirements for each trial (see Appendix B). Correct responses were marked with a + on the data sheet and incorrect responses were marked with a -, then the percentage of correct trials per day for each target were input into an Excel sheet and graphed using a line graph. Materials presented to the participants were a collection of 4-inch x 4-inch picture cards that depicted the targets contained in each matrix.

Validity. Data collection procedures involved direct observation of participants during sessions by the instructional aide working with the participant. A trained second observer was present for at least 20% of sessions, during which time each observer had a copy of the data sheet, and data was compared at the end of each session. Inter-observer agreement was found to be 100%. All instructional aides and observers were previously trained to use DTT methods (i.e., rapid presentations of discriminative stimuli, prompting, and consequences for responding). Data recording and treatment implementation training for all instructional aides that working with the participants during baseline (Phase A), treatment (Phase B), and generalization (Phase C) occurred prior to the study. The procedures utilized in the study were cited in research (see Axe & Sainato, 2010; Dauphin, Kinney, Stromer, & Koegel, 2004; Frampton et al., 2018; Kohler & Mallot, 2014). Additionally, treatment fidelity was measured using the Treatment Fidelity Data Sheet (see Appendix C), which was completed by the second observer during the sessions. The Treatment Fidelity Data Sheet evaluated the extent to which the researcher followed the protocols for providing the correct environmental and instructional cues and feedback procedures outlined on the data sheet during the session.

Reliability. Reliability information was obtained by having an observer attend at least 20% of sessions. All instructional aides included in the study attended a training on data recording and treatment implementation in which they received the opportunity to practice collecting the data. As mentioned above, both observers recorded data on student responses on separate data sheets and compared at the end of each session. A percent of agreement was calculated by looking at the number of agreed upon data points divided by the total number of data points, then multiplied by 100 (Berk, 1979). A 100% IOA score was determined at the end of the study.

Data collection. Data was collected using a data sheet specifying the stimuli presented to the student as well as what the expected response should be (see Appendix B). Student responses were marked as a + if they responded correctly and a - if they responded incorrectly. Five trials per target occurred for each participant daily, and data from sessions was input in an Excel document that translated the data into a line graph. Baseline data was depicted using open circles whereas teaching data was a solid circle. Transitions between phases were noted on the line graphs using labeled dashed lines.

Fidelity. Intervention fidelity refers to the extent an intervention is implemented as it is supposed to be; it is imperative that this is taken into account when analyzing the effectiveness of treatments (McGee, Lorencatto, Matvienko-Sikar, & Toomey, 2018). As such, instructional aides were trained in data recording and intervention implementation strategies prior to the study and received hands-on training in which they practiced following the data collection and treatment implementation procedures. Additional data on treatment fidelity was monitored through the use of the Treatment Fidelity Data Sheet (see Appendix C) by a second observer present for 20% of sessions for each participant. Fidelity was calculated by dividing the number of correctly implemented sessions by the total number of sessions observed. For Emily, staff implemented the study according to outlined procedures for 91% of observed sessions. Charles' staff implemented the study with 96% fidelity, as did Amanda's staff. Feedback was given to staff in the moment if inaccuracies were observed.

Social Validity. At the completion of the study, all 19 inter-raters completed a four-point Likert scale (i.e., *1 = strongly disagree to 4 = strongly agree*) social validity questionnaire (See Appendix D). The questionnaire, adapted from Berger, Manston and Ingersoll (2016), consists of six questions designed to understand the perceived usefulness, significance and satisfaction with the implemented intervention (Kennedy, 2005). Participant responses were kept confidential and responses were summarized. Overall, 74% of the inter-raters strongly agreed that the treatment was effective for their student. 79% of inter-raters strongly agreed that matrix training was acceptable for increasing the students' skills and that the skills learned would remain at an improved level even after treatment ended. 63% of the inter-raters said the intervention quickly improved their student's skills. Lastly, 90% of inter-raters strongly agreed with the statement that they would recommend the treatment to others, and 100% of them strongly agreed that they would be willing to carry out the treatment themselves in the future. A closer look at the raw data from the questionnaire shows that the inter-raters who scored lower on certain items (i.e., the treatment was effective, it was acceptable for increasing student skills, skills learned would likely be maintained, and the treatment quickly improved their student’s skills) were primarily staff working with Charles, who performed significantly lower during the generalization phase than both of the other participants in the study.

Ethical Considerations

One ethical consideration was that if the hypothesis was not supported, the student's rate of learning over a given amount of time may decrease. That is, matrix training was used to select a smaller number of targets than normal to teach a student in hopes that using a matrix would increase the number of stimuli the student is able to respond to correctly after the intervention. For example, if a student typically learned five targets at a time, but only three were selected for teaching during the matrix training intervention, the number of learned targets in the same amount of time may be smaller if the intervention did not lead to increased generalization. Another ethical consideration was maintaining confidentiality of participants; therefore pseudonyms were used throughout the study and any other personally identifiable information was excluded. Additionally, because the participants demonstrated some challenging behaviors, it was important to consider the ethical implications of involving them in this study. For this reason, students with severe or high rates of challenging behaviors (e.g., aggression, self-injury, non-compliance) were excluded from the sample. Similarly, if at any point during sessions a participant began engaging in severe or high rates of challenging behavior, the session was terminated. Additional considerations were put in place to ensure participation in the study would not take away from participants’ abilities to complete their regularly scheduled IEP programming throughout the day. For this reason, participants were not to exceed 5 research sessions per day. The prolonged baseline sessions for participants 2 and 3, characteristic of a multiple-baseline across participants study, was an ethical concern for several reasons; the participants may have become frustrated when asked to do something new without assistance, and they could potentially practice providing incorrect responses without consequence which could possibly strengthen inaccurate responding. Baseline sessions were not administered daily to participants 2 and 3 but rather at staggered intervals to mitigate these possibilities while still adhering to multiple-baseline procedures. Lastly, because results showed that the hypothesis was supported and matrix training was highly effective for all participants, the intervention will be considered for use with other students across the school.

Validity threats. Bias was one potential extraneous variable in the study. It was important to ensure that no subtle or unconscious cues were given to the student during each phase of the intervention to minimize confounding variables. Having a second observer present who took treatment fidelity data controlled for this possibility. During each session, the second observer marked on the Treatment Fidelity Data Sheet (see Appendix C) whether or not the person implementing the intervention with the participant responded as directed to do so by the data sheet. An additional threat to validity was that the intervention took place during sessions throughout the school day, and we were unable to control for what was taught outside of the sessions during school. If a participant had been learning other 2-component labels during the time of intervention, the data obtained in the study may not accurately reflect the success of the intervention. To ensure independence of behaviors we did not select participants who currently had an IEP goal for labeling pictures with 2-components.

Data Analyses

Data was collected for each session with each participant and translated on Excel into a line graph. A visual analysis of the data collected for each phase of the study was performed for each participant. Additionally, the percent of non-overlapping data (PND) procedure described by Scruggs, Mastropieri, and Casto (1987) was calculated across phases to determine the effect size. This percentage was calculated for each participant by dividing the number of data points that did not overlap between the generalization and baseline phases by the total number of data points collected.

Results

The results demonstrating the effect of matrix training on 2-component labeling in young adults with ASD are depicted in Figure 1. The y-axis measures the participants' total percentage of correct responses. The x-axis shows the days during which the study took place. The dotted line divides the baseline, intervention, and generalization phases of the study.

Participant 1

As shown in Figure 1 below, Amanda responded correctly in 0% of the baseline sessions. In the intervention phase, her scores had a range of 66-100% and a mean of 97%. In the generalization phase, Amanda responded with a range of 98-100% and a mean of 99%.

Participant 2

Figure 1 shows Charles' scores during the study. In baseline, his responses were consistently at 0%. During the intervention phase, Charles responded with a range of 93-100% and a mean of 99%. His scores in the generalization phase fell within a range of

36-53% and a mean of 42.5%. Student absences and community instruction (e.g., volunteering, shopping) contributed to some of the extended periods of time between data points.

Participant 3

Emily's scores are depicted in Figure 1 below. The scores in baseline show that she responded with 0% accuracy. In the intervention phase, her scores demonstrate a mean of 100%. Her scores in the generalization phase reflect 100% responding for all 3 days in this phase. Due to time constraints, the study was terminated before Emily was able to complete the final phase.

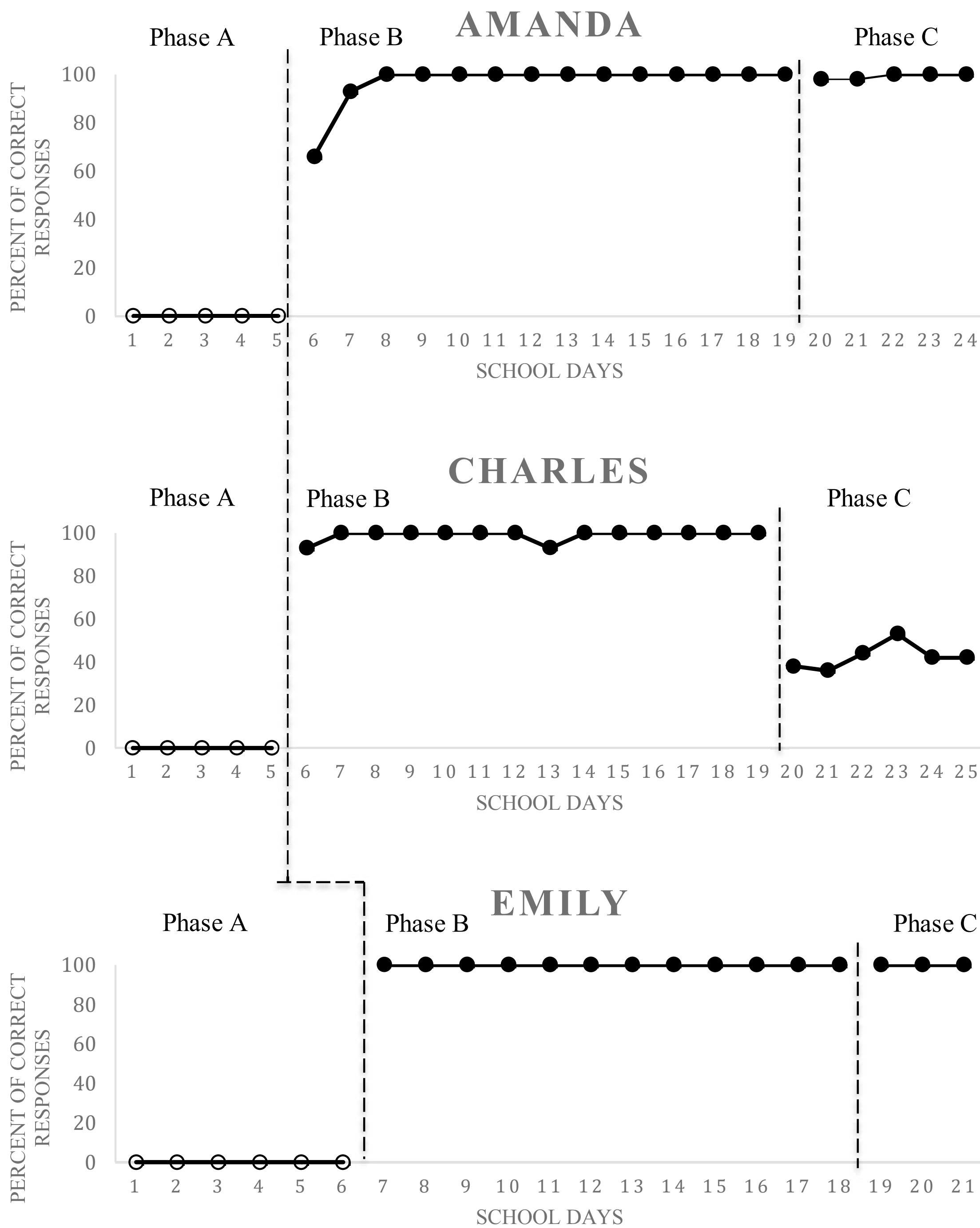

Figure 1. Participants' scores are depicted in the line graph. The y-axis measures the participants' percentage of correct responses, and the x-axis shows each day during the study. Baseline data is depicted with an open circle and changes between phases of the study are noted with a dashed line.

Discussion

Communication challenges often faced by individuals with autism can impede social interactions and thus negatively impact functioning in social settings (Alpern & Zager, 2007; Seltzer et al, 2003). This becomes increasingly important in adolescence, as this is when there is an emphasis on community integration and functional life skills. While there are a variety of instructional strategies that have been shown to be effective in teaching individuals with autism to demonstrate some of the needed communication skills, there continue to be challenges with the amount of time and effort they can require (Schreibman et al., 2015). Matrix training was developed as a potential way to solve these challenges. Prior research has demonstrated the effectiveness of using matrix training to teach a variety of language skills to individuals with ASD (Axe & Sainato, 2010; Dauphin, Kinney, Stromer, & Koegel, 2004; Frampton, Thompson, Bartlett, Hansen, & Shillingsburg, 2018; Kohler & Mallot, 2014). In a previous study in which matrix training was used to teach 2-component labels to children with ASD, they found that it was effective in promoting generalization of the concepts taught to the participants. Based on this information, it was hypothesized that the intervention in the present study would be also be effective in promoting generalization of color-shape combinations in young adults with ASD.

The skill of labeling pictures with two components (i.e., color and shape) was selected to be taught to the participants in the study. For each of the participants, the percent of non-overlapping data (PND) was calculated by dividing the number of non-overlapping data points by the total number of data points. Only data points in the baseline and generalization phases were used for calculation. All participants demonstrated a PND score of 100%, indicating that the intervention was highly effective.

Looking closely at each participant's scores, there are some individual differences in responding that should be noted. Emily responded consistently and accurately during the intervention phase, indicating that the errorless learning and prompt fading strategies used were effective. Once she reached the generalization phase, she was able to respond with 100% accuracy over the course of all three days. Similarly, Amanda responded consistently during the intervention phase; however, her scores showed that she responded inaccurately to some of the pictures for the first two days of intervention. This could indicate that the type of prompting used was not fully effective for her, whereas it was effective for Emily.

Charles' scores remained fairly consistent throughout the intervention phase, but responding dropped significantly when the generalization phase was initiated. This highlights some individual differences that he as a learner may have. In looking at the raw data during the generalization phases, it can be seen that Charles was able to maintain correct responding for all 3 taught targets, but responded inconsistently to the untaught targets in the matrix. Although consequences were provided for incorrect responses (i.e., error correction procedures) in the generalization phase, it appears that this alone was not sufficient to teach Charles the new targets. This suggests that he has a tendency toward rote responding, and highlights a need for this to continue to be an area of focus for his instruction. Other studies have evaluated the use of teaching multiple matrices or having post-treatment "booster" sessions to improve participants' responding when they did not initially demonstrate generalization of taught concepts (Frampton et al, 2018; Kohler & Mallot, 2014); utilizing some of these approaches may have benefitted Charles.

Another look at the raw data showed some interesting consistencies across all three participants in that each participant began correctly and independently responding to the question “what is it?” before prompts had been fully faded. That is, before the staff had a chance to provide a prompt, the student had already correctly labeled the pictures. This suggests that the prompt fading procedures could have been more efficient if the prompts were faded quicker. Fading the prompts quicker would decrease the amount of time spent in the intervention phase and allow participants to move more quickly to generalization phase, thus maximizing instructional time. It is also possible that individualizing prompt fading procedures for each participant would address this issue (Seaver & Bourret, 2014); that way, personal learning history and rate of acquisition of new skills could be accounted for.

Limitations and Future Directions

There were several limitations to this study. First, the number of staff involved in the study as the students’ primary instructional aides was 19. With this many staff members, training each of them to effectively implement the procedures with fidelity was a concern. Prior to the study, staff attended a group training in which procedures were discussed and modeled. However, during IOA sessions once the study began, it was noted that there were some inconsistencies with staff following procedures. Staff were given in-the-moment feedback when this occurred, but it may have been beneficial to have more extensive staff training before the study or ongoing staff trainings.

Another limitation to the study was ensuring participants could complete their daily sessions without interrupting their regularly scheduled activities. Because the participants selected were young adults, their IEP programming consisted of many community-based instructional tasks. This meant that they were off-site and unable to participate in the study for between 1 and 4 hours daily. This resulted in difficulties with getting enough data to count towards sessions, which ultimately led to a limited number of sessions. This contributed to the low number of baseline sessions across participants. Additionally, managing each participants' schedule and planning for IOA sessions at a time when both the participant and the inter-observer were present was difficult. It may have been helpful to select a 'team leader' for each participant that could serve as the inter-observer for that participant rather than have one person serve as the inter-observer for all three participants. This would potentially eliminate some of the scheduling challenges that arose during the study.

The last limitation for this study was the limited amount of time in which the study could take place. Had the study been longer, it is possible that additional areas related to matrix training could have been addressed. For example, it could have looked at the participants' ability to maintain their learned skills over a period of time by doing less frequent maintenance probes. Additionally, the last participant was unable to complete the final phase of the study because of the time limit on the research; future studies would benefit from increased durations. A minimum of 2 or 3 months would be beneficial for assessing the effectiveness of this treatment over time.

Overall, the findings from this study affirm prior research. However, additional research is warranted to determine the usefulness of this intervention with a more diverse population of learners. It would also be beneficial to examine the use of matrix training to teach more complex language skills and with a variety of other instructional strategies besides DTT.

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Appendix A

Adjective + Noun Matrix

	Circle	**Square**	**Triangle**
Red	Red Circle *	Red Square	Red Triangle
Yellow	Yellow Circle	Yellow Square *	Yellow Triangle
Green	Green Circle	Green Square	Green Triangle *

Targets with an * are the targets along the diagonal line selected for teaching during Phase B

Appendix B

2-Component Labels Data Sheet

Participant:_____________ Date: ______________

Target	Stimulus Conditions	Consequence	Prompt Level	+/-	+/-	+/-	+/-	+/-
Red Circle	**During a discrete trial session, experimenter will present participant with the picture of the red circle and ask "what is it?" Participant will respond "red circle" verbally or with AAC.**							
Red Square	**During a discrete trial session, experimenter will present participant with the picture of the red square and ask "what is it?" Participant will respond "red square" verbally or with AAC.**							
Red Triangle	**During a discrete trial session, experimenter will present participant with the picture of the red triangle and ask "what is it?" Participant will respond "red triangle" verbally or with AAC.**							
Yellow Circle	**During a discrete trial session, experimenter will present participant with the picture of the yellow circle and ask "what is it?" Participant will respond "yellow circle" verbally or with AAC.**							
Yellow Square	**During a discrete trial session, experimenter will present participant with the picture of the yellow square and ask "what is it?" Participant will respond "yellow square" verbally or with AAC.**							
Yellow Triangle	**During a discrete trial session, experimenter will present participant with the picture of the yellow triangle and ask "what is it?" Participant will respond "yellow triangle" verbally or with AAC.**							
Green Circle	**During a discrete trial session, experimenter will present participant with the picture of the green circle and ask "what is it?" Participant will respond "green circle" verbally or with AAC.**							
Green Square	**During a discrete trial session, experimenter will present participant with the picture of the green square and ask "what is it?" Participant will respond "green square" verbally or with AAC.**							
Green Triangle	**During a discrete trial session, experimenter will present participant with the picture of the green triangle and ask "what is it?" Participant will respond "green triangle" verbally or with AAC.**							

Appendix C

Treatment Fidelity Data Sheet

	Y/N /NA	Y/ N/ NA	Y/ N/ NA	Y/ N/ NA	Y/ N/ NA
Environmental conditions consistent with stimulus conditions					
Instructional cues presented according to stimulus conditions					
No extraneous cues presented during session (e.g., indirect prompts)					
No feedback (e.g., reinforcement or error correction) provided to student (during baseline phase only - NA if taking data during treatment/generalization)					
Reinforcement and error correction procedures used as outlined (during treatment and generalization phases only - NA if taking data during baseline)					

Appendix D

Social Validity Questionnaire

Questions:		**1 Strongly disagree**	**2 Disagree**	**3 Agree**	**4 Strongly Agree**
1	This treatment was effective				
2	I found this treatment acceptable for increasing the student's skills				
3	I think the student's skills would remain at an improved level even after the treatment ends				
4	This treatment quickly improved the student's skills				
5	I would be willing to carry out this treatment myself if I wanted to increase the student's skills				
6	I would suggest the use of this treatment to other individuals				